HAROKOPIO UNIVERSITY OF ATHENS
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QUANTITATIVE VERIFICATION STATISTICS OF WRF PREDICTIONS OVER THE MEDITERRANEAN REGION

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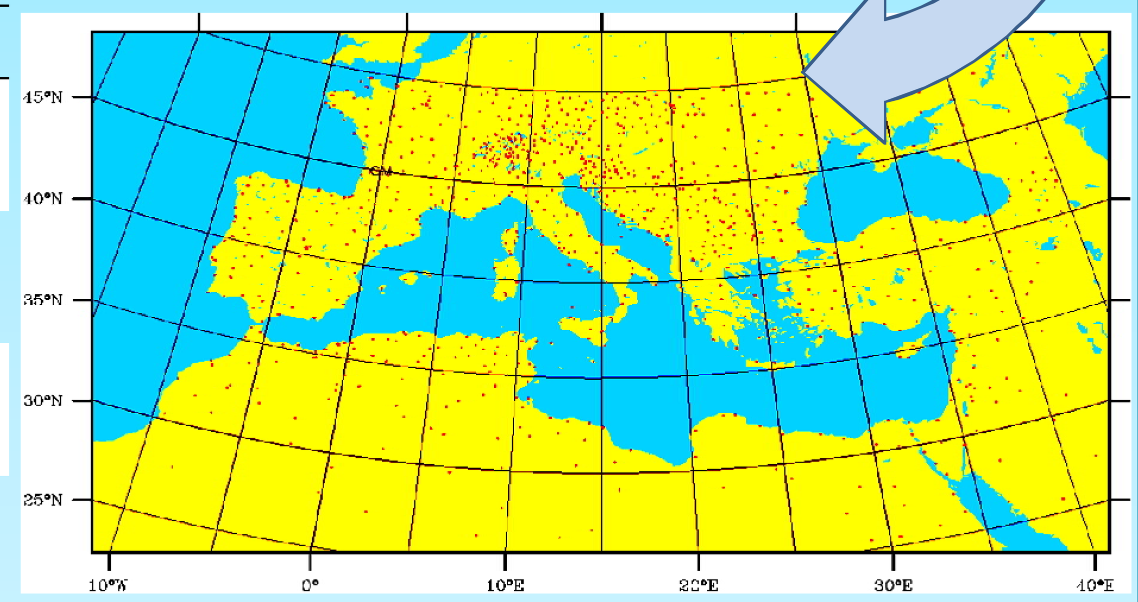
1. Introduction

The Weather Research and Forecasting (WRF) limited area model with the embedded Non-hydrostatic Mesoscale Model (NMM) dynamical core has been installed and appropriately configured in the parallel computing infrastructure of the Department of Geography at Harokopio University of Athens in order to provide regional forecasts for the entire Mediterranean basin and the Black Sea. In the present study the performance of the WRF weather forecasts has been assessed using as reference the surface measurements available from the World Meteorological Organization network. Surface observations from 935 conventional stations were used to verify and compare categorical model forecasts of 10-m wind field and 2-m air temperature every 3 hours and the accumulated 6-h precipitation for two consecutive years (2009 and 2010).

WRF-NMM characteristics

Horizontal resolution (# grid points)	0.09°x0.09° (305x273)
Vertical resolution	38 sigma-pressure levels
Initial&Boundary conditions	GFS-NCEP (0.5°x0.5°) 3-h update
Microphysical scheme	Ferrier (*Ferrier et al., 2002*)
Cumulus scheme	Betts-Miller-Janjic (*Janjic et al., 2001*)
Surface layer scheme	Monin-Obukhov-Janjic scheme (*Janjic, 1996*)
Land-surface model	4-layers NOAH (*Chen and Dudhia, 2001*)
Planetary boundary layer scheme	Mellor-Yamada-Janjic Level 2.5 (*Janjic, 1996*)
Radiation scheme (long-shortwave)	GFDL (*Schwarzkopf and Fels, 1991*)

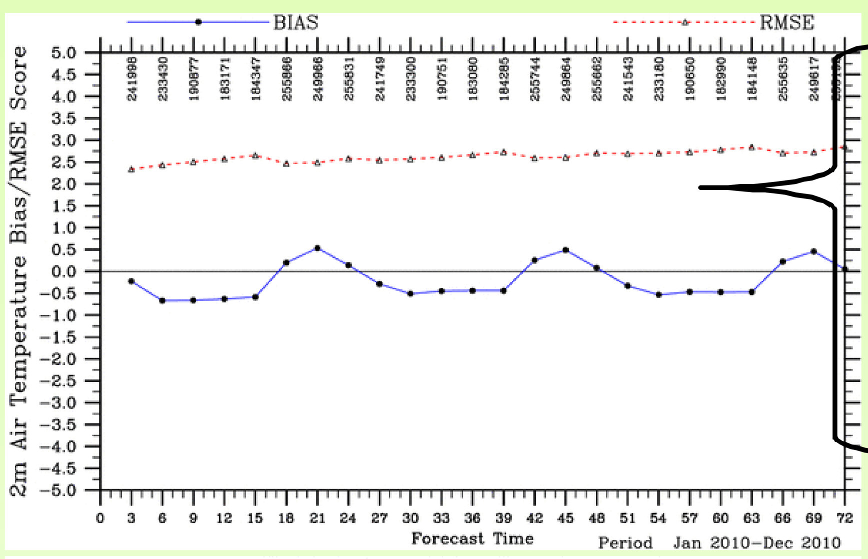


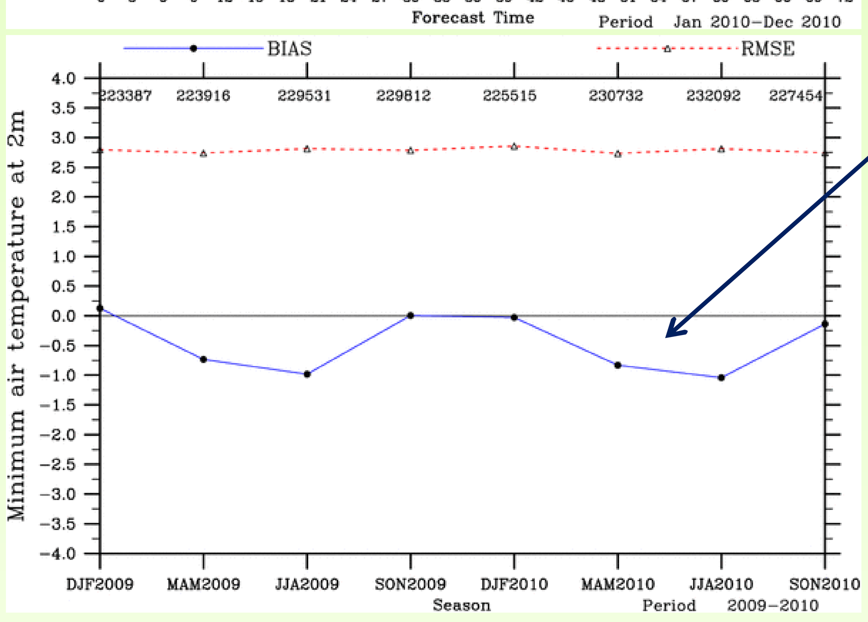
		Observed		
		Yes	No	
Forecast	Yes	a	b	a+b
	No	c	d	c+d
		a+c	b+d	n=a+b+c+d

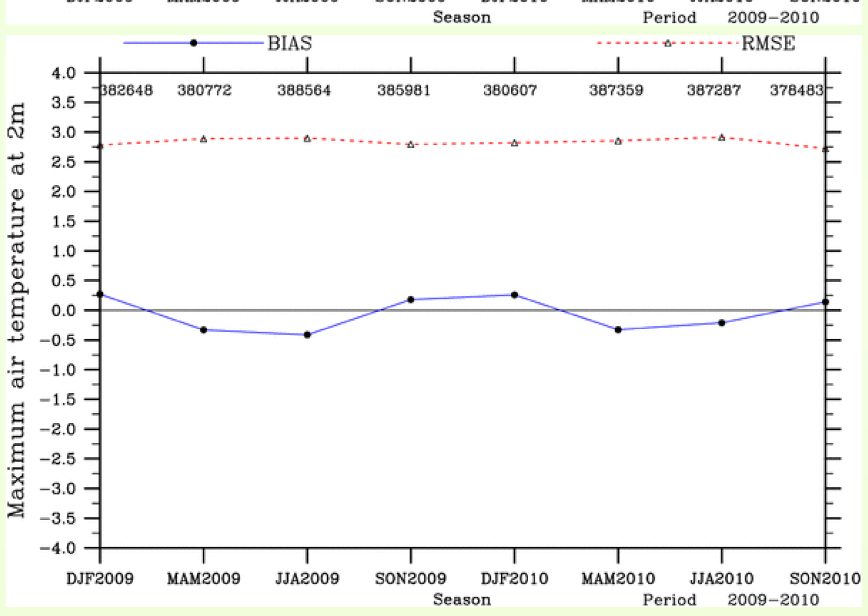
Statistical scores (Papadopoulos & Katsafados, 2009)

Continuous variables	Bias	$bias = \frac{1}{N}\sum_{i=1}^{N}(F_i - O_i) = \overline{F} - \overline{O}$
	RMSE	$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(F_i - O_i)^2}$
Discrete variables	Bias	$B = \frac{a+b}{a+c}$
	ETS	$ETS = \frac{a - a_r}{a+b+c-a_r} \quad a_r = \frac{(a+b)\cdot(a+c)}{a+b+c+d}$

2. Continuous variables

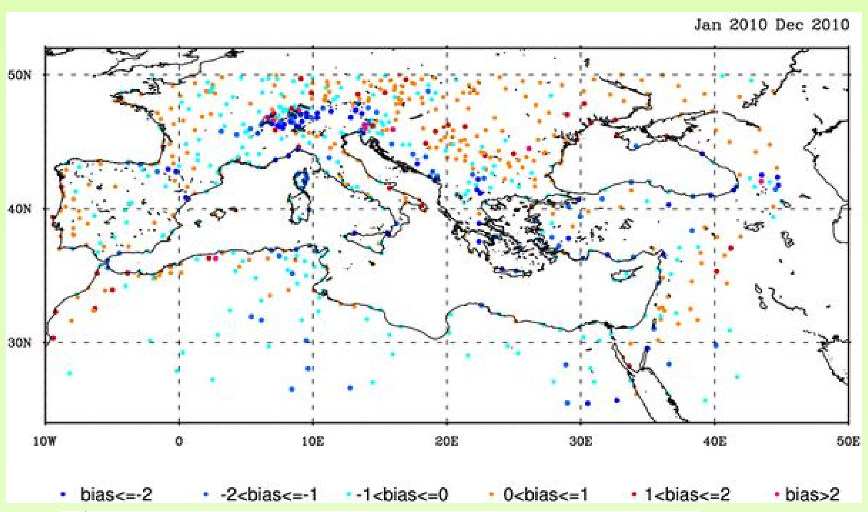


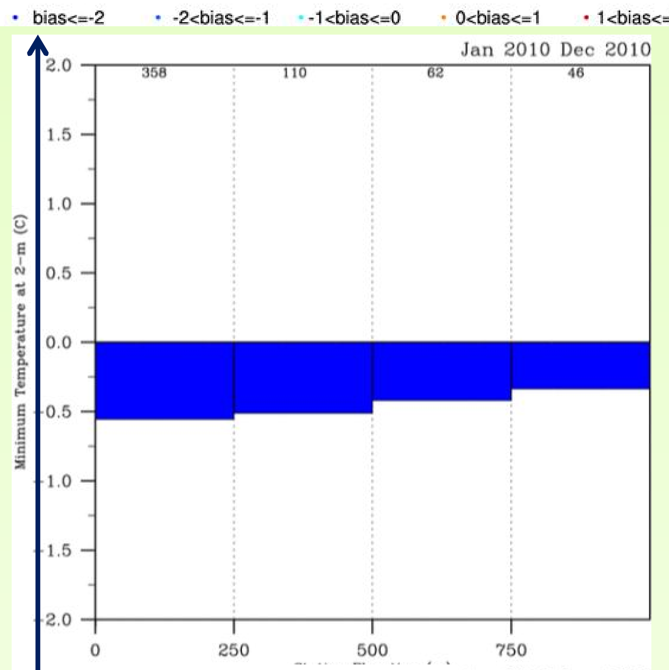


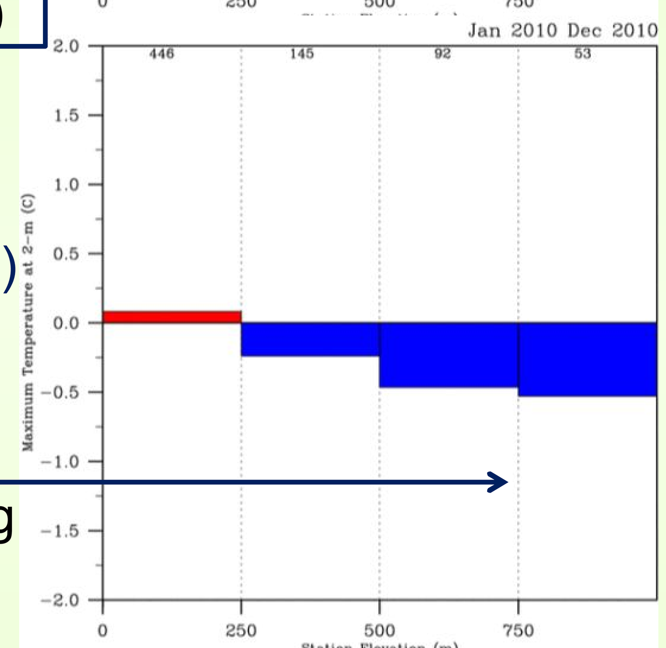


2.1 Temperature at 2-m

- Steady RMS error (~2.7°C) for the entire forecast period
- +0.5°C overestimation at day time
- -0.7°C underestimation during evening hours
- RMSE independent of the season (~2.7°C)
- Cold, up to -1°C, bias of the minimum and maximum temperatures on the transient and summer seasons
- Overestimation of the maximum temperatures up to +0.5°C on winter
- Underestimation (bias<=-2°C) at the mountainous stations and over northern Africa
- Systematic cold bias of the minimum temperatures (-0.5°C) for the stations under 250m
- The maximum temperatures were underestimated up to -0.5°C for elevations exceeding the 750m

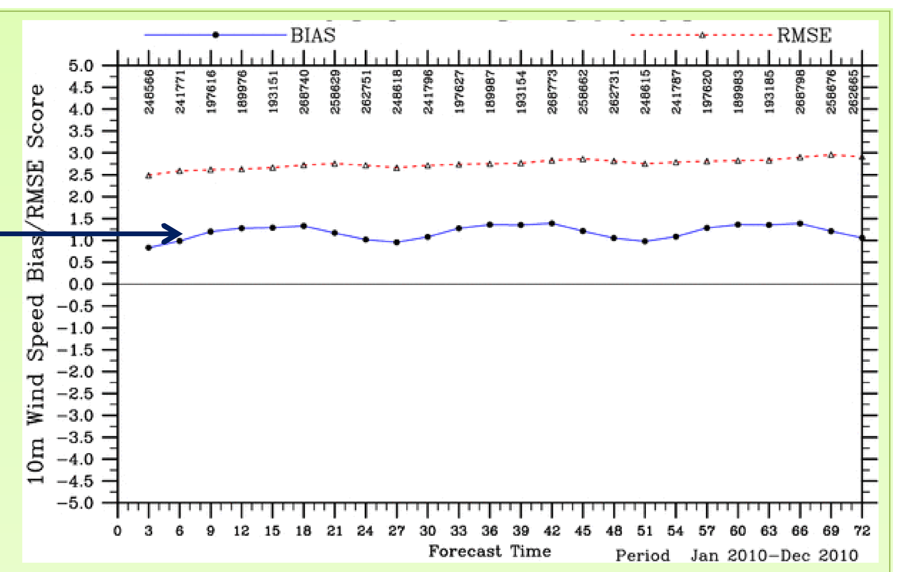


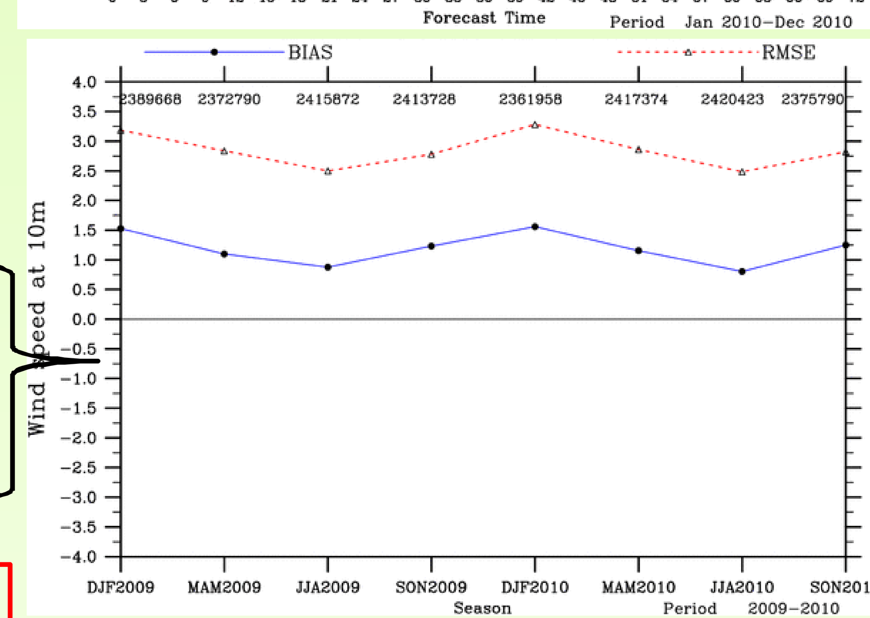


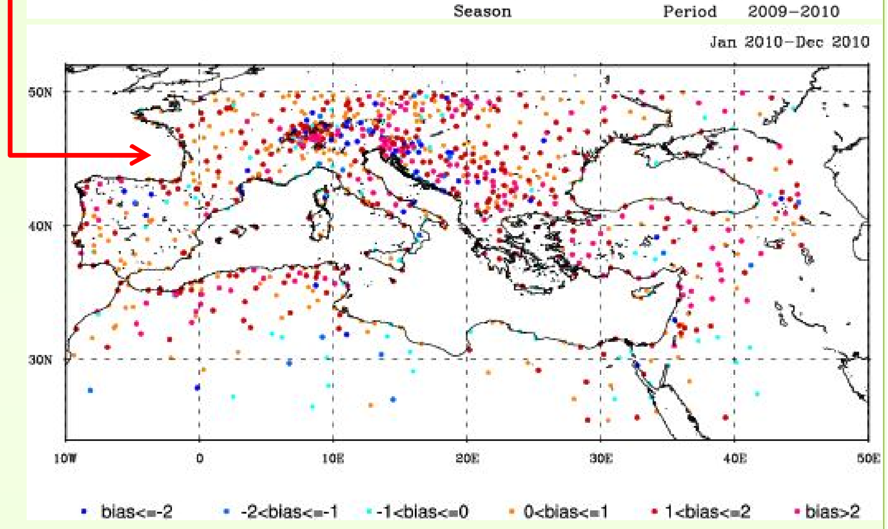


2.2 Wind Speed at 10-m

- Systematic overestimation up to 1.5 ms^{-1} during evening hours
- RMSE remains almost constant (2.5-3 ms^{-1}) for the entire forecast time
- Autumn and winter mostly contributed to the overestimation
- Bias >= 2 ms^{-1} over the most stations in Europe and the northern Africa
- The stations located at low and moderate altitudes mostly contributed to the wind speed overestimation

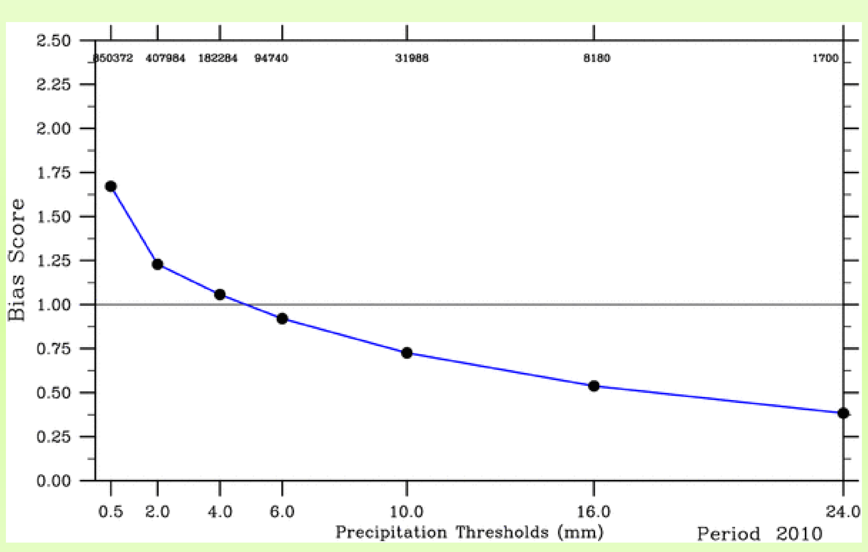


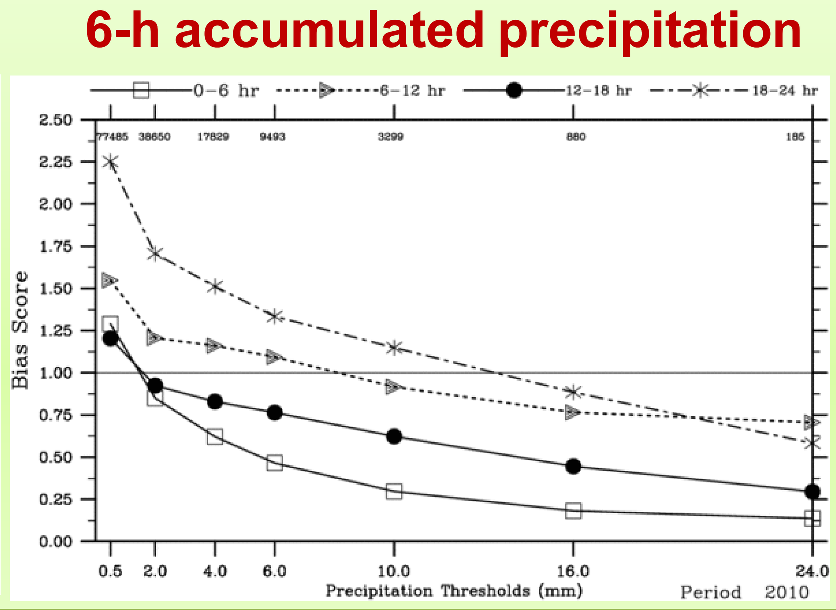


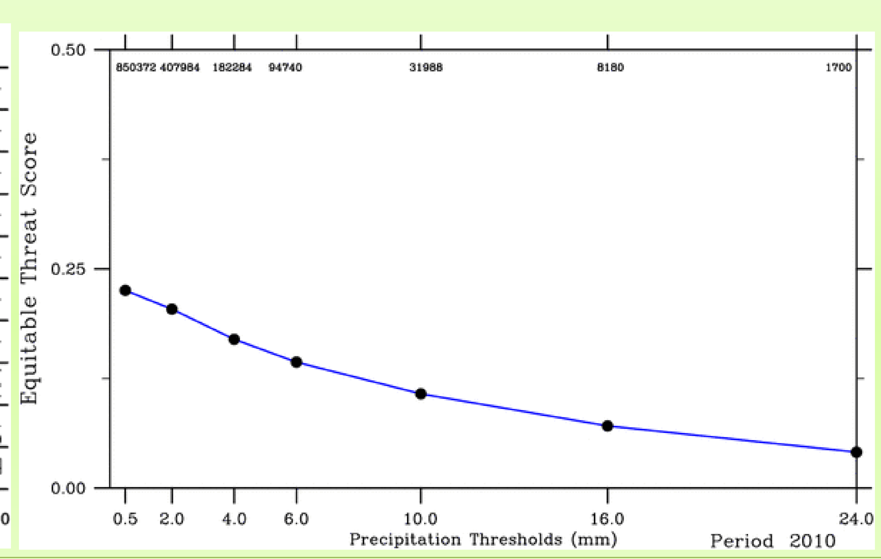


3. Discrete variables

6-h accumulated precipitation







- The bias score was rapidly decreased from 1.75 to 1 for the light to moderate precipitation threshold values and slowly to 0.4 for the heavy precipitation.
- Overestimation of the light-to-moderate (0.5-6 mm) thresholds, more prominent at the day time, and underestimation of the medium-to-high thresholds (6-24 mm).
- The ETS was continuously decreased indicating a rapid decay of predictive skill.

4. Concluding remarks

✓ WRF near surface temperature predictions indicated a diurnal signal, in which the moderate cold bias on evening hours turned to warm bias during daytime. The seasonal distribution of the statistical scores revealed a cold bias of the minimum and maximum temperatures for the transient and summer seasons. The minimum temperatures indicated a systematic cold bias at the stations located under the 250m while the maximum temperatures were underestimated for the elevations exceeding the 750m during the transient and summer seasons. This may be attributed to the model domain inadequate representation of terrain characteristics.

✓ The wind speed at 10-m was systematically overestimated. The definition of the forecast error local maxima during the evening hours and over the cold period of the year suggests a rather unrealistic description of the near surface heat and momentum fluxes. The stations located at low and moderate altitudes mostly contribute to the wind speed overestimation. This may in part be related to the discrepancy between the elevation represented in the model domain and the actual elevation at which observations were made.

✓ The light-to-moderate (0.5-6 mm) precipitation was overestimated, especially on the day time, while the medium-to-high thresholds (6-24 mm) were underestimated for the entire forecast period.